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10 April 1963

MEMORANDUM FOR THE RECORD

SUBJECT : A-12 Propulsion System Matching

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REFERENCE : [redacted], dated 26 March 1963 titled "A-12 Propulsion System Matching"

1. This report is for the purpose of updating information formulated since the release of reference memorandum and should be read in conjunction with it.

2. Two coincident but probably separate problems appear to be emerging. Current information based upon the the immediate phenomena surrounding these problems indicates that they are likely separately induced but jointly contributory toward the overall aircraft functional characteristics noted in the Mach 2.0 to 2.5 flight regime. Most flight test data based upon the twelve flights made to date in the Mach 2.0 to 2.5 regime reveals (1) an extraordinary engine rotor speed decrease and (2) an extraordinary aircraft roughness or vibration coupled with markedly damaged aircraft ejector trailing edge flaps.

a. The decrease in engine rotor speed appears to be induced by some undefined characteristic inherent in the installation or mating of the engine to the airframe. Full scale high Mach and altitude engine testing in the Pratt & Whitney altitude facility in Florida has been unable to duplicate this speed decrease encountered in flight. On the other hand, at least eight different engines installed in two different aircraft have demonstrated similar rotor speed decreases during similar flight conditions. Comparison of engine flight test data with engine altitude facility data points toward a different control schedule requirement for the same rotor speed between the two installations. This says that with the same control schedule a different rotor speed will result between the two installations. The conclusion drawn from this indicates the altitude facility is not representative of the aircraft installation.

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in the Mach 2.0 to 2.3 regime with engines in afterburning, the engine nozzle position (nozzle area) governs engine rotor speed. If rotor speed tends to decrease, the main fuel control senses this tendency and reschedules the nozzle to a wider open position, allowing rotor speed to retain the constant level existing prior to the tendency to decrease. Flight data indicates that the engine nozzle has become airflow saturated (maximum area wide open) before it should. Further control, therefore, of rotor speed is nonexistent. When additional rotor speed perturbations occur, such as engine bleed bypass opening which increases turbine backpressure and nozzle airflow, the nozzle wants to open further to relieve this backpressure and, therefore, maintain rotor speed, but cannot do so. Rotor speed, therefore, must decrease. Explanations of this extraordinary rotor speed decrease as a function of premature nozzle saturation center around two areas:

(1) Since the engine main fuel control governs nozzle position and therefore rotor speed, it must be examined certainly as a factor in the chain of events and also as a potential cause of the trouble.

If the control, which depends upon engine burner pressure, aircraft inlet pressure, and aircraft inlet temperature signals for proper scheduling of fuel flow, nozzle position, and rotor speed, senses any one of the above signals incorrectly or if these signals are false in that they misrepresent the real condition of the total mass airflow, improper scheduling can result. Flight and ground test experience to date indicates that the signals are being sensed correctly by the control but does not indicate that the signals themselves are or are not representative of the total mass airflow in flight. Flight instrumentation is being incorporated to examine the validity of these signals.

This same instrumentation will provide a basis for examining the control itself as a potential cause of the trouble. In this area a basic incompatibility

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between design rotor speed schedule, nozzle position schedule, and installed mass airflow could be the trouble.

(2) The airframe inlet in addition to providing properly stable airflow to the engine, also dictates the environment within which the engine main fuel control sensory signals originate. Inlet recovery, defined as the total air pressure available at the engine face relative to free stream ram air pressure, as established by proper spike and bypass door position will affect the condition and amount of airflow available to the engine but will probably not affect the validity of the sensory signals to the engine main fuel control.

Inlet airflow distortion characterized by local low and high pressure areas at the engine face can affect the validity of the sensory signals to the engine main fuel control. In fact, distortion resulting in an unrepresentative low pressure at the main fuel control burner pressure signal probe, could trigger an engine reaction identical to that being experienced. The very meager inlet flight instrumentation heretofore in use indicated as much as 15% pressure distortion at the engine face on at least one flight. Lockheed design data indicates also that as much as 15% pressure distortion at the engine face can exist in the Mach 2.0 to 2.5 regime at 3° aircraft angle of attack. Instrumentation consisting of 40 pressure readings at the engine face to accurately define this distortion in flight is being provided.

b. Examination of the airframe ejector after flight on those aircraft powered by the J-58 engines reveals considerable physical flap damage in addition to distinct overheating. That all of the noted aircraft roughness during flight in the Mach 2.0 to 2.5 regime can be attributed to ejector flap vibration is questionable. That the flaps are vibrating excessively and overheating is not questionable. Under proper operation, secondary airflow drawn by the ejector from the airframe inlet and through the nacelle provides the smooth transition from convergent to divergent flow for the engine exhaust plume inside the ejector in addition to providing a cooling air cushion between the ejector flaps and the engine exhaust plume. The overheating of the flaps indicates that this secondary airflow is either nonexistent or deficient. Without this secondary airflow, the high Mach engine exhaust plume can impinge on the flaps establishing a local shock with attendant violent turbulence resulting in flap vibration and excessive drag. Some flight experience has revealed that further closing of the inlet bypass doors appeared to have distinctly reduced the magnitude of vibration. This would fit the pattern because less bypass door opening means less airflow overboard spillage through the doors which means more captured airflow available to augment the ejector secondary airflow requirement.

A factor tending to aggravate the above condition may be the geometry change attendant with the 30K afterburner. This afterburner incorporates an eleven square foot nozzle area which is one square foot larger than that of the 28K afterburner. This larger nozzle opening could enhance engine exhaust plume impingement on the ejector flaps.

Information to date does not lead to a definite connection between this ejector phenomenon and the extraordinary reduction in engine rotor speed.

Flight instrumentation is being provided to examine ejector flap operation and secondary airflow. Pratt and Whitney is now rebuilding model hardware representative of the current ejector and engine nozzle configuration for windtunnel testing.

3. In summary, it would appear that a much better but still incomplete definition of the problem exists now than existed two weeks ago. Action underway to improve this definition includes the following, some of which has already been cited in the above paragraphs:

a. Continue the flight test effort to optimize inlet spike and bypass door scheduling.

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b. Provide an increase from 5 to 40 pressure readings at the engine face to better examine inlet recovery and inlet distortion.

c. Provide more accurate and consistent flight instrumentation to examine inlet temperature, inlet pressure, burner pressure, and fuel flow as involved in the engine main fuel control for the definition of rotor speed reduction.

d. Provide instrumentation to examine ejector flap operation and secondary airflow.

e. Continue the altitude testing of two development engines in Florida. As the newly instrumented flight data becomes available, it will be integrated with the program in an effort to duplicate flight conditions.

f. Pursue latest engine nozzle/ejector configuration model testing at the Hartford windtunnel.

g. Continue engine main fuel control bench testing particularly in the area of rapid transients from very cold to hot environmental temperatures.

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